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## Feature Article

## Use of Helmet-Based Noninvasive Ventilation in Air Medical Transport of Coronavirus Disease 2019 Patients

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## A B S T R A C T

Helmet-based noninvasive ventilation (NIV) is a viable option for the safe transport of potential or known coronavirus disease 2019 patients. Given the most likely modes of transmission through droplets, aerosols, and fomite contact, airway procedures such as endotracheal intubation place air medical crews and other health care providers at high risk for exposure. This, together with data that suggest that a large cohort of coronavirus disease 2019 patients have better outcomes if we can avoid intubating them, creates a need for a safe method of NIV or high-flow oxygen delivery during transport. Commonly used and successful in-hospital regimens for these patients are high-flow nasal cannula and continuous positive airway pressure or bilevel positive airway pressure. In some studies, helmet NIV has been shown to be a viable, if not superior, alternative to these therapies for patients with acute hypoxemic respiratory failure. Furthermore, because it is a sealed and closed space that completely isolates the patient's airway and breathing, it provides a very high degree of protection from exposure to pathogens transmitted through droplets or aerosols. This article discusses practical implementation of helmet NIV in air medical transport.

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An air medical transport helicopter was requested for an interfacility transport from a small rural emergency department to a tertiary center. The patient was a 60-year-old man with rapidly worsening shortness of breath and weakness. He had been experiencing a fever for approximately a week and had a positive coronavirus disease 2019 (COVID-19) nasal swab test. In the emergency department, the patient was placed on bilevel positive airway pressure (BiPAP) because of severe hypoxemia and respiratory distress with little improvement.

After assessment and patient report, the crew discussed with the referring provider the use of a noninvasive ventilation (NIV) helmet as the most suitable therapy for this patient during transport. The crew prepared the equipment and donned appropriate personal protective equipment. The assessment found the patient in a high Fowler's position, alert, and tolerating the BiPAP well. The patient had a dusky appearance with cyanotic extremities and labored respirations with a rate of about 24 to 28 breaths/min. The patient's oxygen saturations were in the mid-80s. The rest of the vital signs were relatively normal. The crew confirmed the patient was a good candidate for the NIV helmet and did not have any contraindications for its

use. The crew explained the therapy to the patient and provided him with hearing protection for the transport. When attempting to place the helmet over the patient's head, the crew accidentally damaged the neck seal, which rendered it unusable, and they had to obtain another kit, hence the importance of careful application of the device. The next NIV helmet was applied successfully, and a tight neck seal was obtained. The crew placed the patient on the ventilator in the highflowO<sub>2</sub> mode with a flow of 60 L/min and an initial fraction of inspired oxygen (F<sub>IO<sub>2</sub></sub>) of 100%. To preserve oxygen available for transport, they connected the ventilator to the hospital's high-pressure oxygen supply. The patient tolerated the helmet well and did not complain of any discomfort. The crew administered a small dose of midazolam before applying the helmet to reduce the patient's anxiety and continued to do so periodically during the transport. After only a brief time in the helmet, the patient reported feeling better, and the crew observed improvement in respiratory effort and rate. The patient's oxygen saturations improved into the mid-90s. The crew calculated that based on the amount of oxygen on board their helicopter and the anticipated flight time of 17 minutes, a safe F<sub>IO<sub>2</sub></sub> was 70%. The crew adjusted the F<sub>IO<sub>2</sub></sub> to that level while still in the hospital to ensure that the patient could tolerate it without deterioration, which he did. The transport was completed without any complications or changes in the patient's condition. At the receiving facility, the patient was transitioned to a high-flow nasal cannula (HFNC).

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**Figure 1.** Demonstration of Helmet NIV Use in a Leonardo AW119Kx

## Discussion

Given the most likely modes of transmission through droplets, aerosols, and fomite contact, airway procedures such as endotracheal intubation place air medical crews and other health care providers at high risk for exposure. This, together with data that suggest that a large cohort of COVID-19 patients have better outcomes if we can avoid intubating them<sup>1</sup>, creates a need for a safe method of noninvasive ventilation or high-flow oxygen delivery during transport.

Commonly used and successful in-hospital regimens for these patients are HFNC and continuous positive airway pressure (CPAP) or BiPAP. In some studies, helmet NIV has been shown to be a viable, if not superior, alternative to these therapies for patients with acute hypoxemic respiratory failure<sup>2,3</sup>. Furthermore, because it is a sealed and closed space, which completely isolates the patient's airway and breathing, it provides a very high degree of protection from exposure to pathogens transmitted through droplets or aerosols. The following is a discussion of practical implementation of helmet NIV in air medical transport based on the experience at Life Link III.

It is worth noting that although this article describes the Sea-Long Helmet (Sea Long Medical Systems, Louisville, KY) used in conjunction with the Hamilton T1 (Hamilton Medical, Bonaduz, Switzerland) ventilator, it is not intended to promote these 2 products specifically. These are merely the devices tested and being used by Life Link III.

The first step is to establish need and use. The helmet is a suitable device for COVID-19 patients who present with hypoxemia and mild to moderate respiratory distress without any current or anticipated airway compromise or altered mental status. Patients who require supplemental oxygen at rates greater than 6 L/min, HFNC, or CPAP/BiPAP are good candidates for helmet NIV. Contraindications to its use include altered level of consciousness, altered mental status, agitation, airway bleeding, nausea/vomiting, copious secretions or inability to safely clear secretions, respiratory failure, or immediate need for endotracheal intubation.

The next step is the evaluation of practical application. The most basic consideration is the aircraft cabin size. The helmet, when applied, may extend several inches above the patient's head; therefore, the ceiling height and the size of the loading door opening are important factors. [Figure 2](#) depicts an individual who is 6 feet tall in a Leonardo AW119Kx, which has a cabin height of 4 feet. This is



**Figure 2.** AW119Kx height clearance

comparable to many popular light helicopters commonly used for air medical transport such as the Bell 206 or 407, the AS350, or the EC130. The height of this particular helmet is approximately 12 inches. There are smaller devices available on the market designed specifically for the transport environment.

Equipment needed for use of the helmet is another important consideration. The helmet can be used in conjunction with a high-flow oxygen delivery device or a ventilator capable of noninvasive ventilation with leak compensation. Some ventilators such as the Hamilton T1 can deliver both of those therapies. Helmet NIV can require significant oxygen flows. The available amount of oxygen on board the aircraft and transport distances are critical factors that must be considered when evaluating the feasibility of the implementation of helmet NIV. Oxygen management and calculations are discussed later on in this article.

When selecting a specific NIV helmet, the criteria to consider are the amount of space needed for the helmet, assembly requirements, the ease

of use and application, and the range of patient sizes it fits. The Sea-Long Helmet is an example of a device that is well suited for air medical transport. It is supplied in relatively compact packaging and fully assembled; it is quick and easy to place on a patient; and its neck seal can be sized and cut to each specific patient, which eliminates the need to carry several different sizes. As long as the neck seal is measured and cut properly, it provides a tight and reliable seal.

As previously mentioned, the helmet can be used in conjunction with 2 different types of devices. Each has its own distinct set of advantages and limitations. The first is high-flow oxygen delivery. The greatest advantage of this option is its simplicity. All that is needed is a flow generator capable of flows of at least 60 L/min and the ability to control the percentage of oxygen delivered. The high total flow is necessary in order to ensure adequate CO<sub>2</sub> elimination from the helmet and prevent CO<sub>2</sub> rebreathing. A single circuit limb is connected between the flow generator or ventilator and a helmet port through a 1-way check valve or a viral/bacterial filter to prevent outside contamination in the case of accidental disconnection of the circuit. A second helmet port is used to provide outflow from the helmet through a viral/bacterial filter and a positive end-expiratory pressure (PEEP) valve. The PEEP valve provides CPAP as well as positive pressure inside the helmet needed to inflate it, and to generate a neck seal. Generally, a PEEP of 10 cm H<sub>2</sub>O is a safe minimum pressure that ensures an adequate seal.

The limitation of this therapy is the constant flow. Because the flow does not increase during the patient's inhalation, the pressure inside the helmet may drop with each breath. Patients who are "air hungry" and present with tachypnea and hyperpnea may feel as though they are not able to take adequate breaths. These patients may benefit from true noninvasive positive-pressure ventilation (NIPPV) delivered via the helmet. With NIPPV, the ventilator ramps up flow during inhalation, which can alleviate this complaint. Patients can also receive pressure support if needed.

A typical setup for NIPPV (depicted in Figures 3) is a dual-limb circuit going into a Y with a flow sensor that is attached to the same helmet port as the high-flow oxygen delivery limb. This is the inspiratory or inflow port. An outflow port is again needed and is the same as described previously. It is important to understand that the outflow port is essentially an intentional leak. In order for this therapy to be effective, a ventilator capable of large leak compensation is required. The total flow through the helmet is controlled by adjusting the PEEP valve on the outflow port. The lower the PEEP valve setting, the higher the flow. As with the high-flow oxygen delivery, a total flow of at least 60 L/min is needed to ensure adequate CO<sub>2</sub> washout. In this case, the total flow is a combination of the intended leak and expiratory minute volume measured by the ventilator. Ideally, the ventilator is also capable of measuring the leak in liters per minute and provide this value to the clinicians. Table 1 provides Hamilton T1 settings that can be used to deliver helmet NIPPV.

A critical aspect of helmet NIV is oxygen usage and management. With flows of 60 L/min or greater, the oxygen consumption can be quite high at higher FiO<sub>2</sub> levels. For example, 1,200 L of usable oxygen on board of the aircraft provides 40 minutes of oxygen duration at a flow of 60 L/min and 50% FiO<sub>2</sub>. Therefore, implementation of the helmets can require an entirely new approach to oxygen management. The approach needs to be similar to how we manage aircraft fuel. The crews need to know at any given time how much oxygen they have on board and be able to calculate duration at various flows. Before each transport, the patient's FiO<sub>2</sub> requirement and oxygen usage while on helmet NIV, together with the estimated transport time, must be considered. There must be a sufficient supply of oxygen on board the aircraft plus a reserve (eg, 10 minutes for a helicopter). The amount of oxygen needed to move the patient from bedside to aircraft must be considered by the crew. Oxygen duration and



Figure 3. Sample Helmet Setup

Table 1  
Hamilton T1 Settings That Can Be Used to Deliver Helmet Noninvasive Positive-Pressure Ventilation

Mode	NIV
PEEP/CPAP	10–20 cm H <sub>2</sub> O (set approximately 30% higher than desired)
Pressure support	0–20 cm H <sub>2</sub> O as required by patient (note that at higher pressures, up to 50% may be absorbed by the helmet flexing)
Pressure ramp	0 seconds
Inspiratory trigger	Start at 1 L/min (may need to increase if asynchrony occurs or flow is too high)
Expiratory trigger sensitivity	Start at 5% (may need to increase if asynchrony occurs)
Maximum inspiratory time	Set to 3 seconds to maximize inspiratory flow
FiO <sub>2</sub>	Titrate to achieve target oxygen saturations
Flow	Target 60 L/min (total flow is a combination of expiratory minute volume and measured leak); flow can be increased or decreased by adjusting the PEEP valve on the outflow port, PEEP/CPAP on the ventilator, and inspiratory trigger

CPAP = continuous positive airway pressure; FiO<sub>2</sub> = fraction of inspired oxygen; PEEP = positive end-expiratory pressure.

calculation references (Figures 4 and 5) can simplify this process and improve accuracy.

The final step in the implementation of helmet NIV is the development of a procedure, reference materials, education, and training. A step-by-step reference or a checklist can greatly improve the success rates of application and patient safety, especially considering that this can be a low-frequency intervention with limited ability to practice it outside of the actual patient transport setting. Initial and recurrent hands-on training is necessary to obtain and maintain proficiency. The amount and complexity of education and training is largely dependent on the clinicians' experience with various forms of noninvasive ventilation and the equipment used. Flight clinicians who are already proficient at providing CPAP or BiPAP by mask only require minimal training on sizing and applying the helmet and the specific ventilator settings.

Similarly to mask delivered NIV, patients may experience claustrophobia and anxiety, an initial sensation of suffocation, or difficulty exhaling when the helmet is initially applied. A thorough explanation of the therapy and coaching on the proper

## Leonardo AW119Kx Oxygen System

Constant: 0.75	119 Kx Oxygen Duration (h:min)								
	Gauge Pressure (Psi)								
Flow (lpm)	400	600	800	1000	1200	1400	1600	1800	2000
4	0:37	1:15	1:52	2:30	3:07	3:45	4:22	5:00	n/a
6	0:25	0:50	1:15	1:40	2:05	2:30	2:55	3:20	
8	0:18	0:37	0:56	1:15	1:33	1:52	2:11	2:30	
10	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00	
15	0:10	0:20	0:30	0:40	0:50	1:00	1:10	1:20	
20	0:07	0:15	0:22	0:30	0:37	0:45	0:52	1:00	
25	0:06	0:12	0:18	0:24	0:30	0:36	0:42	0:48	
30	0:05	0:10	0:15	0:20	0:25	0:30	0:35	0:40	
35	0:04	0:08	0:12	0:17	0:21	0:25	0:30	0:34	
40	0:03	0:07	0:11	0:15	0:18	0:22	0:26	0:30	
45	0:03	0:06	0:10	0:13	0:16	0:20	0:23	0:26	
50	0:03	0:06	0:09	0:12	0:15	0:18	0:21	0:24	
55	0:02	0:05	0:08	0:10	0:13	0:16	0:19	0:21	
60	0:02	0:05	0:07	0:10	0:12	0:15	0:17	0:20	

Figure 4. Example of an Oxygen Duration Table

119 Kx Oxygen Calculations									
<b>Bedside to Aircraft</b>									
Portable (		Psi - 200)	x 0.16	=	tank duration	min -	time to aircraft	min =	reserve
O <sub>2</sub> flow			lpm						if < 5 min, get more O <sub>2</sub> !
<b>Flight</b>									
Aircraft (		Psi - 200)	x 0.75	=	tank duration	min -	time to dest.	min =	reserve
O <sub>2</sub> flow			lpm						if < 10 min, find alternative
<b>Aircraft to Bedside</b>									
Portable (		Psi - 200)	x 0.16	=	tank duration	min -	time to bedside	min =	reserve
O <sub>2</sub> flow			lpm						if < 5 min, get more O <sub>2</sub> !
<b>Ground Transport (if utilized)</b>									
Ambulance (		Psi - 200)	x 1.56	=	tank duration	min -	time to dest.	min =	reserve
O <sub>2</sub> flow			lpm						if < 10 min, find alternative

Figure 5. Example of an Oxygen Calculation Table

breathing technique may help alleviate some of these complications. The helmets are generally manufactured from clear plastic. This, together with the constant high flow of air through the helmet, may also reduce the incidence or severity of claustrophobia. However, some patients may not tolerate the therapy and may require an administration of anxiolytics or may not be candidates for helmet NIV. In these patients, another form of transportation or endotracheal intubation would be indicated.

In the first 10 uses of helmet NIV at Life Link III since its implementation, it was used 9 times for an interfacility transport and once on a scene response. Five patients were confirmed with COVID-19, 3 were suspected to have COVID-19, and 2 patients were considered low risk. All patients were transported in the helmet without incident or complication. None of the patients deteriorated during transport or required endotracheal intubation. In 2 instances, the neck seal was damaged during the initial application of the helmet and required a replacement. There were no cases of the neck seal failing during transport.

## Conclusion

Helmet NIV is a viable option for the safe transport of potential or known COVID-19 patients. Given the need to minimize the risk for exposure to transport crews and the difficulty in predicting which patients may be infectious, this therapy offers a solution to a problem that many air medical transport programs are facing today.

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